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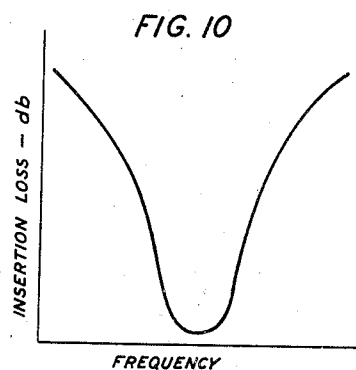
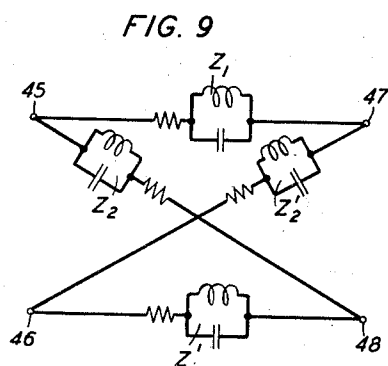
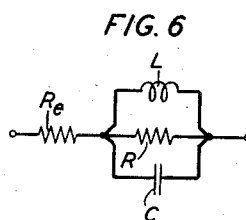
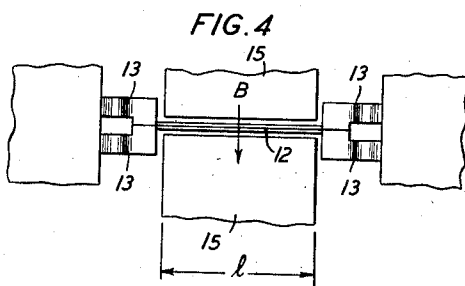
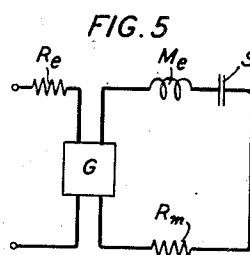
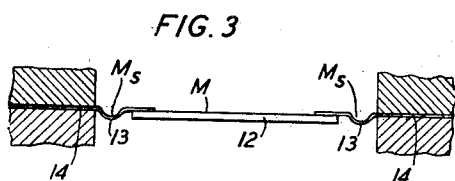
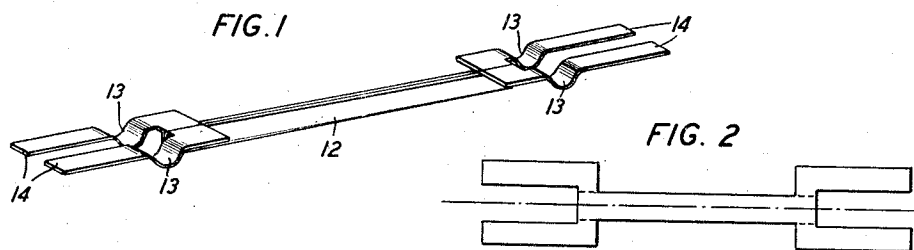
R. B. BLACKMAN ET AL

2,139,220

ELECTROMECHANICAL WAVE FILTER

Filed April 25, 1936

2 Sheets-Sheet 1



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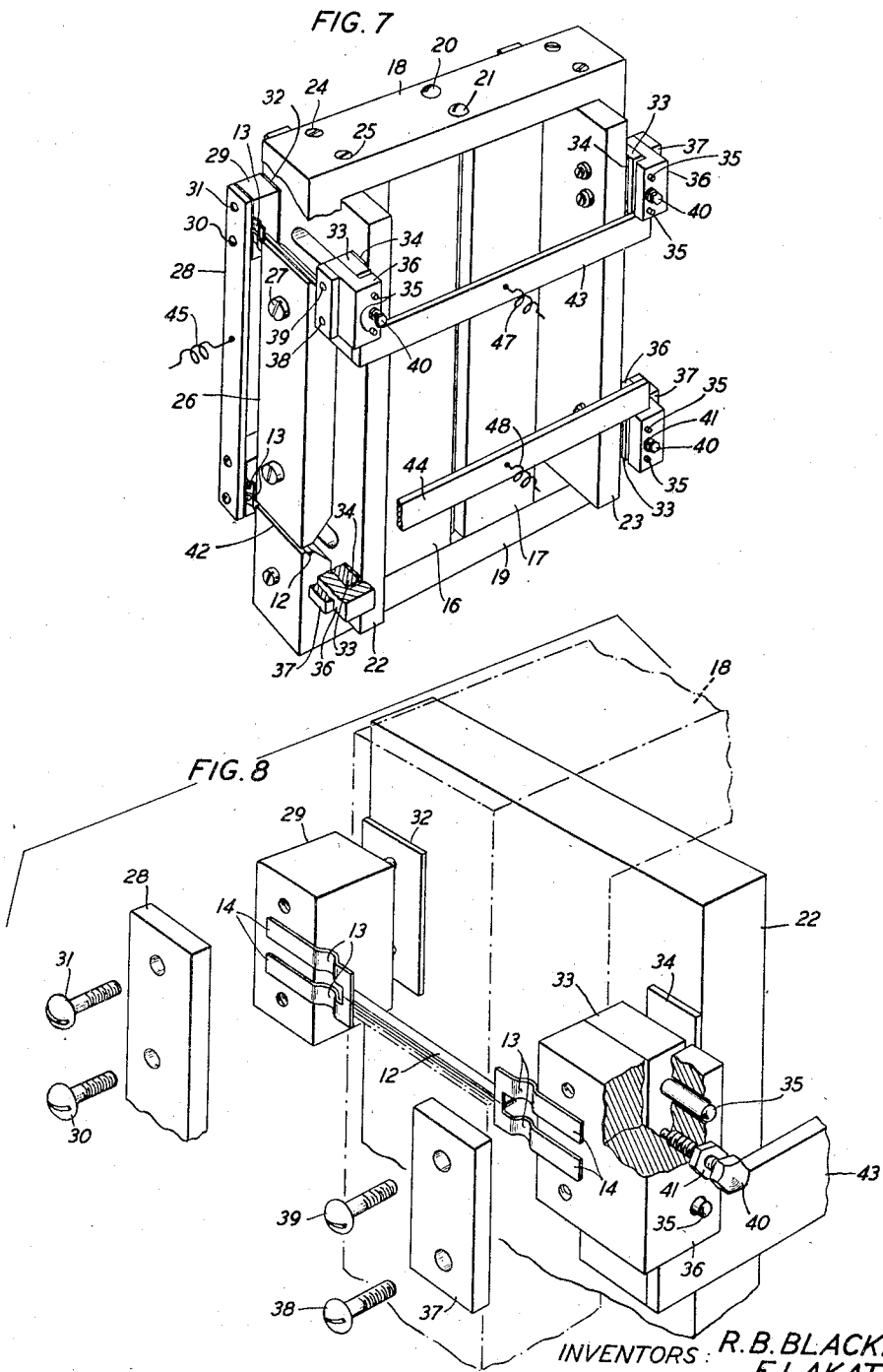
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UNITED STATES PATENT OFFICE

2,139,220

ELECTROMECHANICAL WAVE FILTER

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8 Claims. (Cl. 178-44)

This invention relates to electromechanical wave filters and more particularly to flexurally vibrating elements adapted for use as reactances in such filters.

5 An object of the invention is to increase the frequency range over which electromechanical wave filters may be made to operate successfully.

Another object is to reduce the eddy current losses in an electrodynamic vibrator.

10 A feature of the invention is an electromechanical vibrator having a light but comparatively rigid central portion hinged flexurally at the ends so that the central portion will vibrate as a unit without appreciable bending.

15 In accordance with the present invention there is provided an electromechanical wave filter which may be designed to transmit a band of frequencies centered in a range in which known types of such filters will not operate successfully. The filter has been found to be especially efficient in passing a band of frequencies centered in the range of 2000 to 3000 cycles per second.

20 The filter employs as a reactance element a light but substantially rigid conductor hinged flexurally at its ends and supported in a transverse magnetic field. The hinges may, for example, consist of bent portions of the conductor. Adjustment of the frequency of vibration may be made by varying the tension, thus deforming the bend and changing the stiffness. When an alternating current flows in the element it is set into vibration in a plane perpendicular to the magnetic field. Due to the rigidity of the central portion it tends to vibrate as a unit, the bending being confined to the hinges at the ends. The element will thus have only one principal frequency of vibration, and extraneous resonances will not be introduced. Another advantage is that for a given effective mass of the conductor, 30 a maximum force factor is obtained, thus increasing the ratio of the characteristic impedance of the filter to the effective impedance of one of the reactance elements, which results in decreasing the fixed loss in the transmission band. It is preferable to provide a uniform magnetic field over the entire area of the path traversed by the vibrator in order to reduce the eddy current losses.

35 A number of the vibrators may, for example, be connected in the form of a lattice to provide a wave filter which will transmit a band of frequencies lying between the lower and the upper cut-off. The lattice form has the advantage that the effective resistance of the reactance elements 50 may, in effect, be removed from the filter and in-

corporated in the terminal impedance loads. This results in reducing the attenuation distortion within the transmission band.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying 5 drawings, of which:

Fig. 1 is a perspective view of the electromechanical vibratory element of the invention;

Fig. 2 shows a blank from which the vibrator of 10 Fig. 1 may be formed;

Fig. 3 shows diagrammatically how the vibrator may be supported at its ends;

Fig. 4 shows how the vibrator is positioned in 15 a magnetic field;

Fig. 5 shows schematically the equivalent mechanical circuit of the vibrator;

Fig. 6 represents the equivalent electrical circuit;

Fig. 7 is a perspective view, partially cut away, 20 showing an electromechanical wave filter comprising four vibrators arranged in the form of a lattice network;

Fig. 8 is an exploded view showing in detail the mounting arrangement used for the vibrators; 25

Fig. 9 is the equivalent electrical circuit of the filter shown in Fig. 7; and

Fig. 10 represents a typical insertion loss characteristic obtainable with the filter of Fig. 7.

Fig. 1 is a perspective view showing the preferred form of the electromechanical vibrator of 30 the invention, comprising a substantially rigid central portion 12, bent portions 13 which act as flexural hinges, and flaps 14 at the ends used for mounting. The vibrator may be formed from the blank shown in Fig. 2 cut from a thin sheet of 35 metal. The blank is folded along the center line and then the flaps are bent 90 degrees about the dotted lines. The flaps are then bent to form the hinges. Or, if preferred, the sheet of metal 40 may first be folded into a double layer and then, by the aid of a jig, cut in the shape shown above the center line. The flaps are then bent down at right angles, as before, and by means of another 45 jig the hinges are formed.

In order to minimize the electrical losses, the material used should have a low specific resistance. The material must also be able to withstand the fiber stresses set up in the hinges when the element is in vibration. Aluminum and various 50 aluminum alloys have been found to have characteristics which well fit them for use in constructing the vibrator.

As shown in Fig. 3 the vibrator is supported by means of the flaps 14, which may be clamped be- 55

tween clean brass plates. Electrical connections may conveniently be made through the clamps. The central portion 12 is placed between the poles of a permanent magnet 15, as shown in Fig. 4.

When a source of alternating electromotive force is connected to the ends of the vibrator arranged as shown in Fig. 4 a current flows in the vibrator which by interaction with the magnetic flux causes the conductor to vibrate in a plane normal to the direction of the magnetic field in synchronism with the current variations and to generate a synchronous back electromotive force in the electric circuit. The central portion 12, due to its rigidity, will vibrate as a unit, the bending being confined to the hinges 13. The vibrator will, therefore, have only one mechanical resonance in the frequency range of interest, and will be equivalent to an electrical anti-resonant circuit in series with the electrical resistance of the conductor. Care must be exercised to insure that the magnetic field supplied has no appreciable gradient along the line of motion of the conductor, otherwise eddy currents will be generated and the effective damping will be unduly increased. It is preferable, therefore, that the pole pieces of the magnet 15 extend somewhat beyond the limits of the path traversed by the vibrator.

A schematic representation of the equivalent mechanical circuit is shown in Fig. 5, in which M_e represents the effective mass of the vibrator, S is the stiffness of the hinges, R_m is the mechanical resistance, G is the force factor and R_e is the electrical resistance of the vibrator. The force factor is given by the expression

$$G = Bl \quad (1)$$

where B is the flux density in the air-gap and l is the length of the air-gap as indicated in Fig. 4. The effective mass of the vibrator is approximately the mass M of the central portion 12 plus one-third of the mass M_s of each hinge, as indicated on Fig. 3, and is given by the expression

$$M_e = M + \frac{1}{3}(2M_s) \quad (2)$$

The stiffness S is found from the equation

$$S = \frac{(2\pi f_r)^2}{M_e} \quad (3)$$

where f_r is the resonant frequency of the vibrator.

The equivalent electrical circuit is shown schematically in Fig. 6 which comprises the electrical resistance R_e in series with the three branches L , R and C connected in parallel. The inductance L , the resistance R and the capacitance C are related to the corresponding quantities in the mechanical circuit by the expressions

$$L = \frac{G^2}{S} \quad (4)$$

$$R = \frac{G^2}{R_m} \quad (5)$$

$$C = \frac{M_e}{G^2} \quad (6)$$

The magnitude of the resistance R is generally so large that its shunting effect is negligible, and the equivalent electrical circuit may be considered to be a simple anti-resonant circuit comprising L and C in series with the resistance R_e .

Fig. 7 is a perspective view, partly cut away, showing how four vibrators of the type described above may be incorporated in a wave filter of the lattice type. The filter comprises a permanent bar magnet which may be made in two pieces 16

and 17 to the ends of which are fastened the two pole-pieces 18 and 19 by means of the bolts 20 and 21 which run from one pole-piece to the other between the two portions of the magnet. Two blocks 22 and 23 made of material having a high magnetic reluctance, extend from one pole-piece to the other and are securely fastened thereto by means of screws, such as 24 and 25. The magnetic circuit is completed by means of two inter-polar pieces, such as 26, which are secured to the blocks 22 and 23 by screws, such as 27. There are thus provided four air-gaps, such as 42, in which the vibrators are positioned. The magnet poles are tapered toward the air-gaps to provide a concentrated magnetic field in the neighborhood of the vibrator.

The exploded perspective view of Fig. 8 shows how the vibrators are mounted. At one end, the flaps 14 of the vibrator are held between the two clamping blocks 28 and 29 by the screws 30 and 31 which thread into the block 22. The clamp assembly is insulated from the block 22 by a strip of insulating material 32. At the other end, the block 33 is fastened to the block 22 by screws, or otherwise, and insulated therefrom by the insulating strip 34. The block 33 carries two guides 35 which extend into holes in the clamping member 36, the latter being free to slide upon the guides. The flaps at this end of the vibrator are clamped between the clamping block 37 and the member 36 by the screws 38 and 39 which thread into the movable block 36. Adjustment of the tension of the vibrator is made by turning the adjusting screw 40 which is threaded through the block 36 and bears against the block 33. When the required tension is attained, the adjusting screw 40 is locked by tightening the lock nut 41 against the block 36. As the tension of the vibrator is varied, the curvature of the hinges 13 is changed and in this way the frequency of vibration of the vibrator may be adjusted.

As shown in Fig. 7, the clamp 28 may be extended continuously from one vibrator to another to form an electrical connection. A similar connection, not shown in the figure, is made between the ends of the two opposite vibrators. The other ends of the vibrators are connected electrically by the straps 43 and 44, which may be soldered to the blocks 33. Input connections may be made by soldering wires directly to the straps 28, and output connections to the straps 43 and 44. If desired, some form of terminal may be provided for making these connections, but as such terminals are well known they are not illustrated.

When the connections are made as described above, the network will have the equivalent electrical circuit shown in Fig. 9, having a pair of series impedance branches Z_1 and Z_1' and a pair of diagonal branches Z_2 and Z_2' connected between input terminals 45, 46 and output terminals 47, 48. In accordance with known practice, the resistances shown in series with the branches may be removed from the lattice structure and incorporated with the load impedances, thereby reducing the attenuation distortion within the transmission band. The series and diagonal impedance branches may be proportioned to provide any of a wide variety of transmission characteristics, as explained, for example, in U. S. Patent 1,828,454, issued October 20, 1931, to H. W. Bode. Fig. 10, for example, shows the type of band pass characteristic which may be obtained with the structure of Fig. 7.

What is claimed is:

1. An electromechanical wave filter comprising

a pair of input terminals, a pair of output terminals, an electrical path connecting two of said terminals, means for producing a direct magnetic field and a non-magnetic vibrator conductively connected in said path and disposed in said magnetic field, said vibrator comprising a stiff central portion hinged at each end, whereby the flow of alternating current through said vibrator reacts against said magnetic field to cause said central portion to vibrate as a unit in a plane perpendicular to said magnetic field without appreciable bending.

2. In an electric wave filter, an electromechanical impedance comprising as a mechanical vibratory element a strip of conducting material, means for supporting said strip at its ends and means for providing a magnetic field perpendicular to said strip, said strip having a comparatively rigid central portion at each end of which is a portion adapted to flex whereby said central portion is adapted to vibrate as a unit in a plane perpendicular to said magnetic field.

3. An electromechanical vibratory element comprising means for providing a magnetic field, a vibrator and means for supporting said vibrator in said magnetic field, said vibrator comprising a stiff central portion hinged at both ends whereby when an alternating electromotive force is applied to the ends of said vibrator said central portion will vibrate as a unit in a plane perpendicular to said magnetic field without appreciable bending.

4. In a wave filter, an electromechanical vibratory element comprising means for providing a direct magnetic field, a non-magnetic vibrator having a comparatively rigid central portion and end portions adapted to bend, means for positioning said vibrator in said magnetic field, means for varying the tension of said vibrator to adjust its resonant frequency, a pair of electrical terminals and an electrical path between said terminals including said vibrator, whereby the flow of alternating current through said vibrator reacting against said magnetic field causes said central portion to vibrate as a unit in a plane perpendicular to said field.

5. In a wave filter, an electromechanical reactance element comprising means for providing a

uniform magnetic field, a vibrator having a blade-like central portion with flaps at each end bent at right angles to said central portion, means for clamping said flaps to support said vibrator in said magnetic field, a pair of electrical terminals and an electrical path between said terminals including said vibrator, whereby the flow of alternating current through said vibrator reacting against said magnetic field causes said central portion to vibrate as a unit in a plane perpendicular to said field.

6. In an electromechanical wave filter, a vibrator made from a blank cut from a thin sheet of metal, said vibrator having a comparatively inflexible central portion formed by folding said blank along its center line, and having at the ends flexible flaps formed by bending portions of said blank at right angles to said central portion, means for providing a magnetic field, and supporting means engaging said flaps for positioning said vibrator in said magnetic field, whereby in action bending is confined to said flaps while said central portion remains substantially undeformed.

7. An electromechanical wave filter comprising a pair of input terminals, a pair of output terminals, a magnetic circuit providing four air-gaps, a vibrator supported in each of said air-gaps, and electrical connections for interconnecting said vibrators to form a lattice-type network between said input terminals and said output terminals, each of said vibrators comprising a comparatively rigid central portion with hinges at the ends thereof whereby said central portion is adapted to vibrate as a unit without appreciable bending.

8. An electromechanical wave filter comprising a pair of input terminals, a pair of output terminals, a plurality of electrical paths connecting said terminals, and a plurality of vibratory elements, one of said elements being conductively connected in each of said paths and each of said elements comprising a stiff central portion hinged at each end whereby when alternating current flows through said vibrator said central portion will vibrate as a unit without appreciable bending.

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